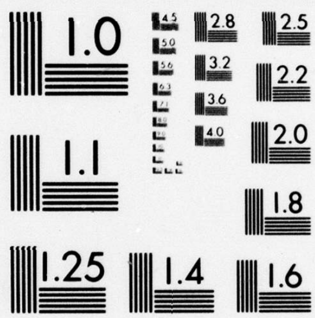
AD-A064 378 FEDERAL AVIATION ADMINISTRATION WASHINGTON D C OFFICE--ETC F/G 10/3
A PROPOSED AVIATION ENERGY CONSERVATION PROGRAM FOR THE NATIONA--ETC(U)
NOV 78

UNCLASSIFIED FAA-AVP-78-12 NL

| OF |

AD
A064378

END
DATE
FILMED
4 -79
DDC




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FAA-AVP-78-12

(13) LEVEL II

# A PROPOSED AVIATION ENERGY CONSERVATION PROGRAM FOR THE NATIONAL AVIATION SYSTEM



Summary Report



November 1978



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Aviation Policy
Washington, D.C. 20591

Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 14 FAA-AVP-78-12 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| 6 A Proposed Aviation Energy Conservation Program for the National Aviation System, Su[redacted] | 11 Nov[redacted]978 |
| | 6. Performing Organization Code |
| 7. Author(s): Office of Aviation Policy | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address: Department of Transportation, Federal Aviation Administration, Office of Aviation Policy, Washington, D.C. 20591 | 10. Work Unit No. (TRAIS) |
| | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address: Department of Transportation, Federal Aviation Administration, Office of Aviation Policy, Washington, D.C. 20591 | 13. Type of Report and Period Covered: 9 Final Rep[redacted]t. |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

12 33p.

16. Abstract


This study presents an overview of potential options for improving aviation energy efficiency. Included in the proposed program are alternatives that could be pursued by the Federal Government as well as options that could be adopted by the various segments of the aviation industry. The report is in four volumes:

- Volume I - The Short Run, 1977-1978;
- Volume II - The Intermediate and Long Run, 1979-1990;
- Volume III- The Proposed Aviation Energy Conservation Program; and
- Summary - Overview of preceding technical volumes.


| 17. Key Words | 18. Distribution Statement |
|---|---|
| Aviation Energy Conservation Program; Revenue Ton-Miles Per Gallon (RTM/G); Policy Evaluation Model, Cross-Impact Analysis; Cost/Benefit Analysis | |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | | |

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

406 648

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# INTRODUCTION

Over the past 25 years, U.S. energy consumption has more than doubled and transportation has consistently accounted for about 25 percent of all energy consumption. Transportation energy is about 97 percent petroleum with 96 percent of aviation energy supplied by petroleum fuels. During the past ten years, the energy consumption of commercial aviation has doubled especially due to the introduction of jet aircraft. By the year 2000, fuel requirements for air transportation are expected to again double.

The Organization of Petroleum Exporting Countries (OPEC) oil embargo of October 1973 and ensuing events have highlighted the problem of a decreasing petroleum supply. The prices and availability of petroleum products are primary concerns to the fuel-intensive aviation industry especially the commercial air carrier sector. Although air carrier fuel consumption for 1976 was 5 percent less than in 1973, domestic and international fuel prices have almost tripled since 1973. In an industry where fuel costs account for about 20 percent of operating costs, the development of fuel-conservative operating techniques and technological improvements to aircraft and the air traffic control system are of paramount importance to the health of the industry.

The Federal Aviation Administration (FAA) has long recognized the need for energy conservation in aviation and official FAA energy conservation efforts predate the OPEC embargo. In March 1972, the FAA's National Aviation System (NAS) Policy Summary warned of the need for more energy-efficient aircraft. The FAA Administrator followed up by calling a Consultative Planning Conference entitled "The Energy Outlook for Aviation" which convened in October 1973. As a result of this prior planning, the aviation community was able to respond immediately when the OPEC embargo was announced October 19.

The FAA implemented a seven-point jet fuel conservation plan on November 20, 1973, which was designed to save almost 4 percent of the total amount of jet fuel consumed by the domestic airlines. The FAA, working closely with the aviation industry, has continued to pursue a dedicated program to conserve fuel in the operation of the Nation's airport and airway system.

The Energy Policy and Conservation Act (EPCA), P.L. 94-163, signed by the President on December 22, 1975, was designed to promote energy conservation in all national sectors. One of the mandates of the EPCA was a 10 percent improvement in energy conservation over 1972, preembargo,

levels. As a result of the prior commitment of the FAA and the aviation community to energy conservation, aviation fuel efficiency, measured in Revenue Ton Miles Per Gallon, was already 16.3 percent above the 1972 level when the EPCA became law.

Despite the improvements already achieved, the need for aviation energy conservation is as great, or greater, today as it was a few years ago. Recognizing the need for an exhaustive, comprehensive program of aviation energy conservation, the FAA initiated this study which presents an aviation energy conservation program consistent with the need to maximize aviation fuel efficiency, without compromising the safety and environmental goals of the FAA.

Existing legislation provides the Secretary of Transportation and the FAA Administrator authority to issue rules and regulations designed to conserve aviation fuel. Sections 103 and 305 of the Federal Aviation Act of 1958 empower and direct the Secretary and the Administrator to regulate air commerce so as to promote its development "in the interest of safety and efficiency," and Section 307(a) explicitly mandates them to develop plans for and formulate policy to insure the efficient use of navigable airspace.

The Department of Transportation Act in Section 2(a) describes the policy objectives as the development of national transportation programs conducive to efficient and convenient transportation consistent with "the efficient utilization and conservation of the Nation's resources." Additionally, the National environmental Policy Act in Sections 101(b)(5) and 105 authorizes every Federal agency to develop and improve its programs so as to "achieve a balance between population and resource use."

Beyond these legislative mandates, the President's energy message of June 29, 1973, directed all departments and agencies to work closely with the Energy Office to develop long-term conservation plans. The Secretary of Transportation was specifically directed to work with the FAA, the Nation's airlines, and the Civil Aeronautics Board to conserve fuel. Furthermore, the mandated role of the FAA in aviation energy conservation policymaking is consistent with the current Administration's emphasis on energy conservation.

The need for an energy conservation program and the policymaking responsibility of the FAA with respect to energy conservation provide the basis for this study. The resulting program includes options which are directly within the purview of the FAA as well as options which are within the purview of the aviation community, which includes the air carrier and general aviation segment, and the airframe, engine, and avionics manufacturers. The FAA's role is to promote and encourage fuel conservation by system users and to provide a safe, efficient environment within which fuel conservation techniques may be practiced by users. The fuel conservation program proposed by the study will dramatically

improve energy conservation within the aviation community, improving airline economics and assisting in the achievement of the national goal of energy conservation.

The energy conservation program in this document is based on the best estimates available at this time. The supporting analysis is briefly reviewed in the next three chapters; however, a full discussion of the methodology and results is contained in Volumes I, II, and III of the study entitled "A Proposed Aviation Energy Conservation Program for the National Aviation System" for which this document is the summary report. The estimates are not meant to be used as exact predictions of fuel savings; rather, this analysis should be a starting point for further refinement as programs are developed and implemented.

## CHAPTER I

## STUDY APPROACH

The study approach for deriving the aviation energy conservation program involves the generation of policy options and the synthesis and evaluation of these options in order to derive an optimal aviation energy conservation program. Thus, there are two distinct methodologies in the study approach: the policy option generation and the program derivation. Volumes I and II of the supporting documents describe the policy option generation methodology for short, intermediate, and long-run options; Volume III combines all the options for the program derivation methodology and final synthesis into the comprehensive aviation energy conservation program. Each methodology is briefly reviewed in this chapter and the assumptions and implications are discussed.

### Policy Option Generation Methodology

A six step policy option generation methodology was utilized. The six steps are: (1) Clarification of the Goal, (2) Progress in Fuel Conservation, (3) Analysis of Conditions, (4) Projection of Developments, (5) Identification of Policy Options, and (6) Synthesis and Evaluation of Policy Options. This six step process results in the identification and preliminary evaluation of a comprehensive set of policy options, which then serve as inputs to the program derivation methodology.

The first step, Clarification of the Goal, was resolved to be the maximization of Revenue Ton Miles Per Gallon (RTM/G) consistent with the other mandated goals of the FAA (e.g., safety). RTM/G is an efficiency measure for aviation fuel utilization and is, therefore, consistent with FAA policy as well as the policy and requirements of the Energy Policy and Conservation Act.

Progress in Fuel Conservation is important in the policy option generation methodology in that it identifies the current level of RTM/G as a beginning point for goal achievement. The use of maximization of RTM/G, as the goal rather than the achievement of a specific RTM/G value, results in some ambiguity. This goal definition affects the policy option generation methodology in that all potential options must be examined, rather than the most obvious or promising ones. Table 1 presents the current goal realization status for aviation energy conservation. Clear progress has been made towards the maximization of RTM/G in that approximately a 30 percent improvement in RTM/G has been realized in the past ten years.

TABLE 1

PROGRESS IN FUEL CONSERVATION

| Year | Air Carrier Revenue Ton Miles (M) | Gallons (M) | RTM/G |
|---|---|---|---|
| 1966 | 8,054 | 4,506 | 1.79 |
| 1967 | 9,982 | 5,789 | 1.72 |
| 1968 | 11,462 | 6,832 | 1.68 |
| 1969 | 13,943 | 8,234 | 1.69 |
| 1970 | 13,877 | 8,085 | 1.72 |
| 1971 | 14,142 | 8,039 | 1.76 |
| 1972 | 15,585 | 8,197 | 1.90 |
| 1973 | 16,707 | 8,538 | 1.96 |
| 1974 | 16,999 | 7,688 | 2.21 |
| 1975 | 17,069 | 7,757 | 2.20 |
| 1976 | 18,802 | 8,104 | 2.32* |

Source: FAA Statistical Handbook of Aviation, CY-1975; and unpublished data from the Civil Aeronautics Board.

*NOTE: RTM/G in 1976 adjusted for increased load factor and used as the baseline RTM/G is 2.25.

The third step, Analysis of Conditions, identified the various factors which can directly affect RTM/G. Technical, socio-political, economic, regulatory, and operational factors were identified.

The trends of the factors identified in the third step were then used in the fourth step, Projection of Developments. Three scenarios were identified: A Most Probable ("surprise-free") scenario, a Potential scenario in which the energy crisis is of reduced importance, and an Uncertain scenario in which another oil embargo or similar petroleum supply constraint is imposed. The trends of the factors were identified for each of the three scenarios. The primary conclusion was that, without an effective aviation energy conservation program, RTM/G would be expected to improve little, if at all, during the coming years.

The fifth step, Identification of Policy Options, involved a comprehensive search for potential fuel conservation policy options. The FAA, the aviation community, and the professional literature served as the primary sources of option identification. Various FAA representatives and FAA documents identified many potential options, particularly with respect to the short run. The Air Transport Association, the airlines, and the airframe manufacturers also provided numerous option ideas. Finally, the professional literature identified numerous, generally long run, options. No other single source was as productive in option identification as NASA's Reducing the Energy Consumption of Commercial Air Transportation (RECAT) study completed in 1976. 1/ These diverse sources resulted in the identification of 103 distinct policy options. These options were then divided into 56 short run (1977-1978), 25 intermediate run (1979-1981), and 22 long run (1982-1990) options. The selection of the breakdown as to short, intermediate, and long run was somewhat arbitrary, reflecting time periods within which primarily operational, airport capacity, and technological options could be implemented, respectively. The initial list of 103 potential policy options was screened to 47 options by deleting those options which were unviable with respect to the FAA charter, of estimated insignificant impact, or impolitic. This first screening left 19 short run, 15 intermediate run, and 13 long run policy options which could serve as components of a potential aviation energy conservation program.

The final step in the policy option generation methodology, Synthesis and Evaluation of Options, required the estimation of a quantitative fuel impact for each option and a final screening of the options for adverse interactions with other FAA goals. The fuel impact was quantified by using the Policy Evaluation Model given in Table 2. Each option was assessed as to which variable in the Model was most affected by the option. An impact calculation was performed for that variable and translated into an impact upon RTM/G through the Model. Assumptions

---

1/ United Technologies Research Center, Cost/Benefit Tradeoffs For Reducing the Energy Consumption of Commercial Air Transportation, East Hartford, Connecticut, NASA Contract NAS2-86086, June 1976.

TABLE 2

THE POLICY EVALUATION MODEL

1. $RTM = \frac{RT}{P} \cdot \frac{P}{S} \cdot \frac{S}{A} \cdot A \cdot M$

2. $\delta RTM = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta A + \delta M$ (See Note 1)

3. $G = \frac{G}{H} \cdot \frac{H}{M} \cdot \frac{M}{D} \cdot \frac{D}{A} \cdot A$

4. $\delta G = \delta\frac{G}{H} + \delta\frac{H}{M} + \delta\frac{M}{D} + \delta\frac{D}{A} + \delta A$ (See Note 1)

5. $\delta\frac{RTM}{G} = \delta RTM - \delta G$ (See Note 1)

6. $\delta\frac{RTM}{G} = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta A + \delta M - \delta\frac{G}{H} - \delta\frac{H}{M} - \delta\frac{M}{D} - \delta\frac{D}{A} - \delta A$ (See Note 1)

7. $\delta\frac{RTM}{G} = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta M - \delta\frac{G}{H} + \delta\frac{M}{H} - \delta\frac{M}{D} - \delta\frac{D}{A}$ (See Note 1)

RTM = Revenue Ton Miles
RT = Revenue Tons
P = Number of Passengers
S = Number of Passenger Seats
A = Number of Aircraft
M = Number of Miles Flown
G = Gallons of Fuel Burned
H = Number of Hours Flown
D = Number of Departures

**Note 1: The above equations are not exact but are satisfactory approximations when the percentage changes are small.**

**Note 2: The operator "δ" represents "percentage change in."**

used in the analysis include the following: (1) the B727 was considered as a "typical" aircraft for evaluating the fuel impact of options, (2) option independence was assumed in that the fuel impact of each option was calculated as if it were the only option implemented, (3) 1975 data were used in almost all cases, (4) forecasts of future fleet sizes and other aviation variables in the FAA's aviation forecasts were utilized, and (5) fuel impacts from NASA's RECAT study and other professional literature sources were considered the best available. As a final step before using the program derivation methodology, each option was evaluated with respect to its impact upon aviation safety, noise, and emissions. Any option compromising safety or aggravating either environmental concern was deleted. This policy interaction screening process deleted three additional options.

The final list of potential policy options for the aviation energy conservation program are given in Table 3. The 42 different policy options listed in Table 3 served as inputs to the program derivation methodology.

## Program Derivation Methodology

The program derivation methodology is described in Figure 1. The 42 policy options are described by a 14 by 42 Base Value Matrix. The Base Value Matrix gives the cumulative fuel impact for each option for each of the 14 years 1977 to 1990, inclusive. This matrix was the outcome of the six step policy option generation methodology described above. A Cross-Impact Matrix, describing quantitatively the impact of each of the 42 policy options upon those remaining was constructed. One or more potential programs was then selected by using the Base Value Matrix and the Cross-Impact Matrix to determine that combination of policy options producing the maximum increase in RTM/G. An economic screen was then applied to each option to assure that the cost of an option did not exceed its fuel conservation benefit. The economic screen deleted any option which had a cost in excess of its fuel conservation benefit. If one or more options were deleted, then the two matrices would be utilized again to find that combination of policy options, less those failing the economic screen, producing the maximum increase in RTM/G. When such a program completely passed the economic screen, it became the proposed aviation energy conservation program. The two crucial methodological steps in the program derivation process are the construction of the Cross-Impact Matrix and the application of the economic screen.

The Cross-Impact Matrix was contructed judgmentally. Most of the options have been tested empirically, on an individual, not a joint, basis. Thus, while the Base Value Matrix contains fairly accurate estimates of the fuel conservation benefits resulting from the implementation of each option in isolation, the option interactions described by the Cross-Impact Matrix are subject to greater uncertainties. If option interactions were ignored, the optimal program would simply be all 42 policy options. However, several options are nonadditive. That is, the fuel impact of implementing two or more options may not equal the sum of the fuel impacts of each individual

## TABLE 3

## POTENTIAL POLICY OPTIONS BY TIME FRAME

### I. SHORT RUN (1977-1978)

- Fuel Advisory Departure (FAD) Procedures
- Wake Vortex Class Sequencing
- Wake Vortex Avoidance Systems
- Area Navigation (RNAV)
- Temporary Construction Runways
- General Aviation Runways
- Snow-Ice Removal Equipment
- Simulators
- Capacity Restraint
- Reseat Existing Aircraft
- Reduce Fuel Tankering
- Climb Procedures in TCA's
- Optimum Descent
- Optimum Cruise Speed
- Optimum Altitude
- Taxi on Fewer Engines
- Load to Aft Center of Gravity (CG)

### II. INTERMEDIATE RUN (1979-1981)

- Flow Control Automation
- Area Navigation
- Wake Vortex Avoidance Systems
- Alternative Ground Movement of Aircraft
- Fog Dispersal Systems
- Performance Measurement and Evaluation Program
- JT8D Retrofit
- JT10D/CFM56 Retrofit
- Derivative Aircraft
- Lighter-Than-Air Vehicles
- Winglets
- Wingtip Extensions
- Aft Body Modifications
- On-Board Performance Computers

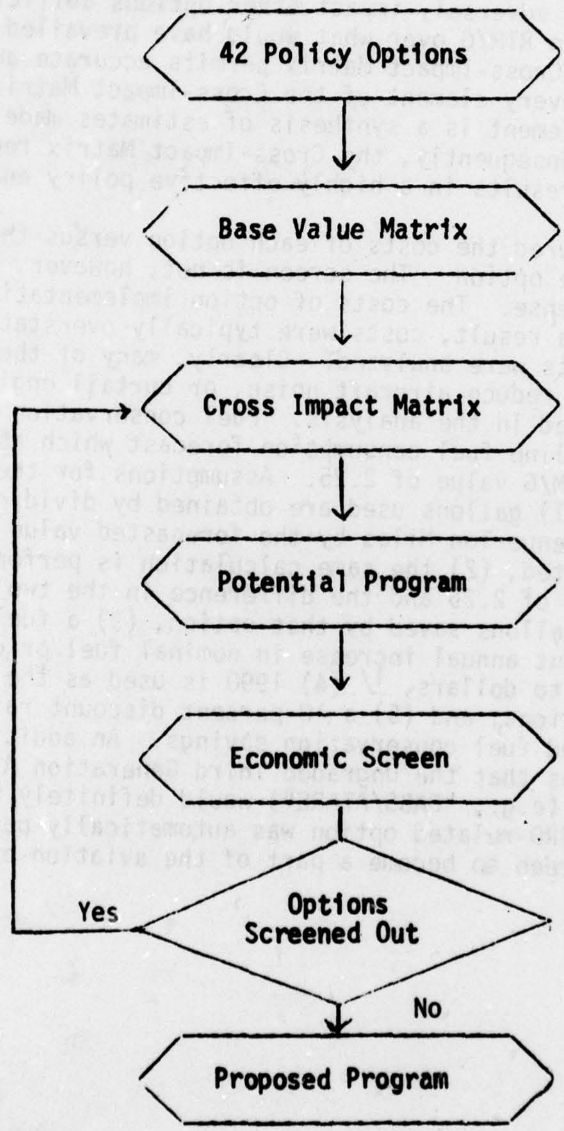
### III. LONG RUN (1982-1990)

- DABS/ATARS
- Post-UG3RD ATC
- Microwave Landing Systems (MLS)
- STOL-Ports/Strips
- Airport Surface Traffic Control (ASTC)
- Advanced Jet Engines
- Digital Electronic Propulsion Control Systems
- Active Controls
- Composite Materials Retrofit
- Supercritical Airfoils Retrofit
- New Near Term Aircraft
- STOL Aircraft
- Large Air Cargo Transports

**NOTE: A full title and brief description of each option is provided in the Appendix.**

FIGURE 1

PROGRAM DERIVATION METHODOLOGY



option. For example, the options "Wake Vortex Class Sequencing" and "Wake Vortex Avoidance Systems" would be expected to produce a joint effect which is less than the impact obtained by adding the two individual impacts.

Ignoring policy option interaction could result in the inclusion of one or more policy options which adversely impact other options sufficiently to result in a net decline in RTM/G over what would have prevailed in their absence. The use of the Cross-Impact Matrix permits accurate and effective policy analysis. While every element of the Cross-Impact Matrix was judgmentally derived, each element is a synthesis of estimates made by at least two aviation experts. Consequently, the Cross-Impact Matrix represents the best available data and results in a highly effective policy analysis process.

The economic screen measured the costs of each option versus the fuel conservation benefits of the option. The screen is not, however, a cost/benefit analysis in the strict sense. The costs of option implementation were invariably ambiguous. As a result, costs were typically overstated. Only fuel conservation benefits were analyzed. Clearly, many of the options enhance aviation safety, reduce aircraft noise, or curtail engine emissions. These benefits are ignored in the analysis. Fuel conservation benefits are calculated versus a baseline fuel consumption forecast which assumes a continuation of the 1976 RTM/G value of 2.25. Assumptions for the benefit calculations include: (1) gallons used are obtained by dividing the FAA official forecast of Revenue Ton Miles by the forecasted value of RTM/G if the option is instituted, (2) the same calculation is performed using the baseline RTM/G value of 2.25 and the difference in the two calculations is the number of gallons saved by that option, (3) a fuel price forecast using a 7 percent annual increase in nominal fuel price per gallon converts gallons to dollars, 1/ (4) 1990 is used as the time horizon for the calculations, and (5) a 10 percent discount rate is applied to both costs and fuel conservation savings. An additional analytical assumption was that the Upgraded Third Generation Air Traffic Control (UG3RD) options (e.g., "DABS/ATARS") would definitely be implemented, so that each UG3RD-related option was automatically passed through the economic screen to become a part of the aviation energy conservation program.

---

1/ Several aviation analysis, including the FAA's Aviation Forecasts, consider 7 percent as the likely long range rate of aviation fuel price increase, however, fuel increases between 1976 and 1977 averaged 17 percent.

# CHAPTER II

## SIGNIFICANT RESULTS

The study approach described in the previous chapter resulted in the derivation of a proposed aviation energy conservation program consisting of 26 policy options integrated into four subprograms. The subprogram areas are: FAA Air Traffic Control, Airports, Aircraft Operators and Management, and Aircraft Technology. The options comprising each subprogram are listed in Table 4. The rationale for partitioning the program options into subprogram groupings is that the FAA's ability to implement the program options is dependent to a varying degree upon decisions made by other members of the aviation community. Clearly, the Air Traffic Control (ATC) subprogram can be implemented by the FAA with some degree of independence. However, the Aircraft Technology subprogram can only be influenced by the FAA. The decision to purchase the new near term aircraft will be made by the air carriers, with possible influence from congressional or other Federal action.

The proposed program includes the implementation of facilities, such as the FAA's Upgraded Third Generation Air Traffic Control System, for which in some cases no specific implementation decisions have been made. In addition, although the entire short run program was not implemented during 1977 as assumed by the analysis, implementation of many of the options is already underway. Assuming full implementation of the proposed aviation energy conservation program, the improvements in RTM/G given in Table 5 would be obtained. It is pertinent to note that the ATC and Aircraft Operators and Management subprograms, the two over which the FAA has the greatest degree of influence, account for at least half the RTM/G improvements until 1985, at which time the impact of the new near term aircraft begins to dominate all other options.

The impact of the aviation energy conservation program is shown in Table 6 which presents a RTM/G forecast. The 1976 value of 2.25 rises to 2.55 in 1980, 2.71 in 1985, and 2.94 in 1990 as a result of full implementation of the program. Recalling that the option generation analysis had projected little or no change in RTM/G in the absence of a program, the rise in RTM/G implies significant savings of both fuel and fuel costs. The program could save 37 billion gallons of fuel between 1977 and 1990 over what would have been consumed had the baseline RTM/G value of 2.25 continued, given the FAA forecasts of RTMs for the period. Assuming a 7 percent annual increase in fuel prices, this translates into a $21.6 billion savings in aviation fuel costs. Even applying a 10 percent discount rate, the present (1977) value of the conserved fuel is $8.9 billion. The year-by-year fuel conservation results are given in Table 7.

## TABLE 4

## THE PROPOSED ENERGY CONSERVATION PROGRAM

### I. FAA AIR TRAFFIC CONTROL SUBPROGRAM

- o FAD
- o Flow Control Automation
- o Wake Vortex Avoidance Systems
- o RNAV
- o DABS/ATARS
- o Post-UG3RD ATC
- o MLS

### II. AIRPORTS SUBPROGRAM

- o ASTC
- o Fog Dispersal Systems
- o Snow-Ice Removal Equipment

### III. AIRCRAFT OPERATORS AND MANAGEMENT SUBPROGRAM

- o Capacity Restraint
- o Reseat Existing Aircraft
- o Simulators
- o Load to Aft CG
- o Reduce Fuel Tankering
- o Taxi on Fewer Engines
- o Climb Procedures in TCA's
- o Optimum Descent
- o Optimum Cruise Speed
- o Optimum Altitude

### IV. AIRCRAFT TECHNOLOGY SUBPROGRAM

- o New Near Term Aircraft
- o Winglets
- o Active Controls
- o On-Board Performance Computers
- o LTA Cargo Vehicles
- o Large Air Cargo Transports

**NOTE: A full title and brief description of each option is provided in the Appendix.**

TABLE 5

CUMULATIVE IMPROVEMENT IN RTM/G

| Subprogram | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. ATC | .95% | 2.10% | 3.19% | 5.37% | 5.95% | 5.97% | 5.99% | 6.05% | 6.12% | 6.17% | 6.21% | 6.29% | 6.49% | 6.55% |
| II. Airports | .06 | .13 | .15 | .21 | .23 | .23 | .28 | .32 | .33 | .33 | .33 | .33 | .33 | .33 |
| III. Aircraft Operations | 2.05 | 4.01 | 4.01 | 4.01 | 4.01 | 4.10 | 4.13 | 4.28 | 4.64 | 5.18 | 5.45 | 5.72 | 5.77 | 5.81 |
| IV. Aircraft Technology | 0 | 0 | 1.54 | 3.69 | 4.70 | 5.15 | 5.56 | 6.85 | 9.40 | 12.84 | 15.03 | 16.86 | 17.40 | 17.80 |
| PROGRAM TOTAL | 3.06 | 6.24 | 8.89 | 13.28 | 14.89 | 15.45 | 15.96 | 17.50 | 20.49 | 24.52 | 27.02 | 29.20 | 29.99 | 30.49 |

TABLE 6

RTM/G FORECAST

| Year | RTM/G |
|---|---|
| 1976 | 2.25 |
| 1977 | 2.32 |
| 1978 | 2.39 |
| 1979 | 2.45 |
| 1980 | 2.55 |
| 1981 | 2.59 |
| 1982 | 2.60 |
| 1983 | 2.61 |
| 1984 | 2.64 |
| 1985 | 2.71 |
| 1986 | 2.80 |
| 1987 | 2.86 |
| 1988 | 2.91 |
| 1989 | 2.92 |
| 1990 | 2.94 |

TABLE 7

PROPOSED AVIATION ENERGY CONSERVATION PROGRAM

FUEL SAVINGS

| Year | Millions of Gallons Saved | Value (M) | Value Discounted at 10% (M) |
|---|---|---|---|
| 1977 | 268.8 | $ 82.8 | $ 82.8 |
| 1978 | 560.9 | 185.1 | 168.3 |
| 1979 | 852.6 | 301.0 | 248.7 |
| 1980 | 1,382.2 | 522.5 | 392.5 |
| 1981 | 1,693.0 | 684.0 | 467.2 |
| 1982 | 1,820.7 | 786.5 | 488.4 |
| 1983 | 1,968.1 | 909.3 | 513.2 |
| 1984 | 2,276.4 | 1,126.8 | 578.2 |
| 1985 | 2,851.0 | 1,508.2 | 703.6 |
| 1986 | 3,599.2 | 2,040.8 | 865.5 |
| 1987 | 4,214.6 | 2,554.0 | 984.7 |
| 1988 | 4,816.3 | 3,125.8 | 1,095.6 |
| 1989 | 5,163.9 | 3,583.8 | 1,141.9 |
| 1990 | 5,616.8 | 4,173.3 | 1,208.8 |
| 1977-1990 | 37,084.5 | $21,583.9 | $8,939.4 |

Furthermore, the analysis has focused on the substantial contributions of the aviation energy conservation program with respect to fuel alone. The program would also produce beneficial effects on aviation safety, engine emissions, aircraft noise, passenger time and comfort, as well as revitalizing the aircraft manufacturing industry.

# CHAPTER III

## CONCLUSIONS AND RECOMMENDATIONS

The proposed Aviation Energy Conservation Program presented in the previous chapter (and described more fully in the Appendix) could produce enormous savings in aviation fuel. The number of gallons of fuel saved per year, previously given in Table 7, is illustrated in Figure 2 wherein the savings are presented by subprogram. In the next few years, ATC and operational changes produce the greatest savings; in the long run, the aircraft technology subprogram provides the most significant savings.

Several conclusions can be drawn under the assumption that the proposed Aviation Energy Conservation Program is implemented in its entirety:

1. The program produces highly significant savings in aviation fuel, averaging 2.6 billion gallons each year over the 1977-1980 period (equal to 32 percent of total 1976 usage).*

2. The program is long-range and optimal in nature. The maximum savings for the entire period is achieved, rather than increasing short run fuel conservation while engendering long run difficulties.

3. The program is realizable and feasible. All options comprising the program are based on known technologies and none of the options conflict with other FAA goals.

The fundamental recommendation is that the program should be initiated as soon as possible by those having prime responsibility. Further program development and analysis will refine the estimates, but would be unlikely to alter them significantly. The primary remaining analysis would consider the problems of program implementation. The implementation of the proposed Aviation Energy Conservation Program would produce important benefits for the aviation community and achieve a major step toward the President's goal of energy conservation.

---

*Note: Total energy savings for the Nation will be slightly less because implementation of the proposed program may require an increase in other energy costs for construction and/or operation of some options.

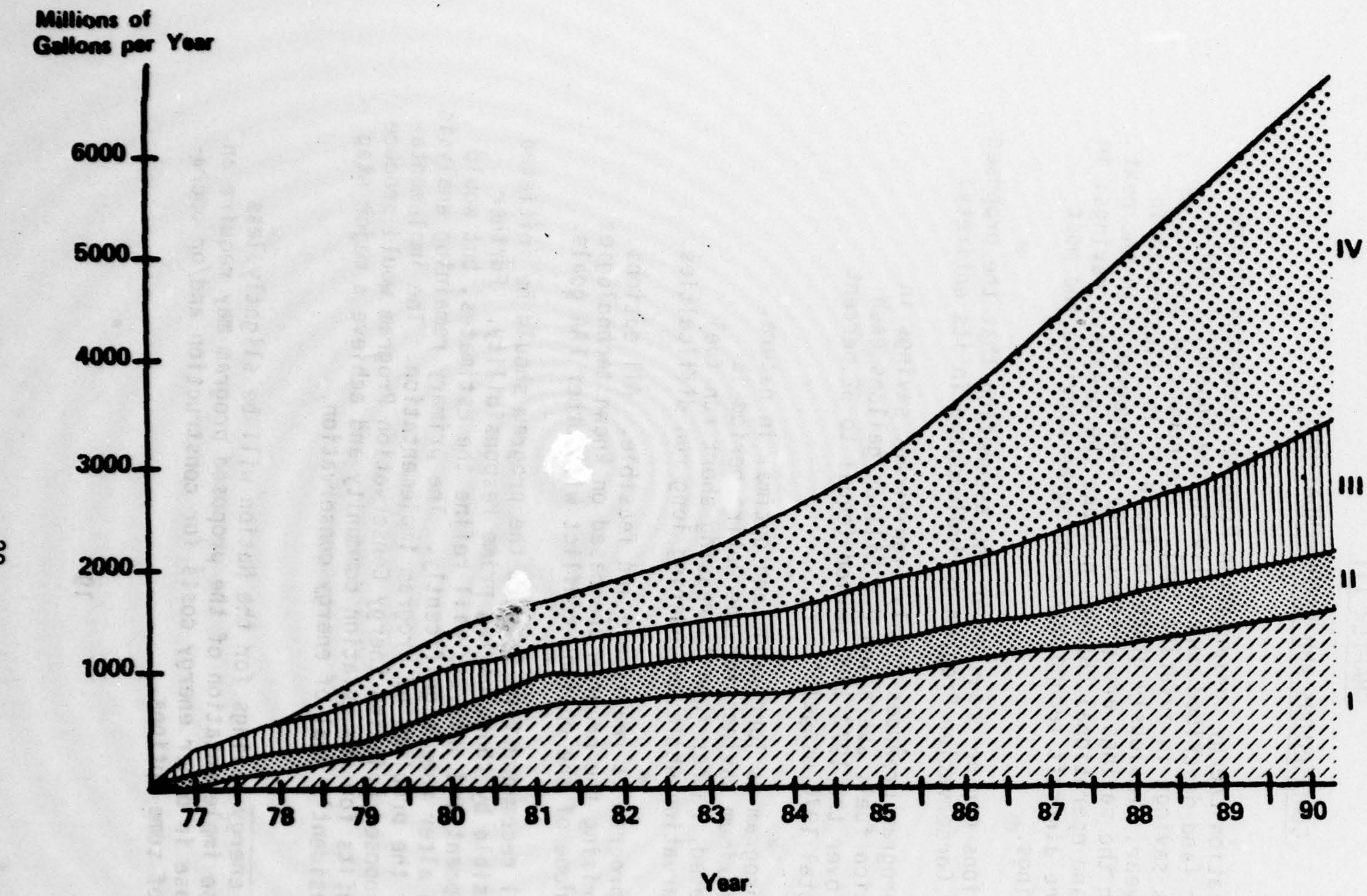



FIGURE 2 GALLONS SAVED PER YEAR BY SUBPROGRAM

I-ATC, II-Airport, III-Operations, IV-Aircraft

# APPENDIX

## DEFINITION OF OPTIONS

# APPENDIX

## DEFINITION OF OPTIONS

A brief description of each of the 26 policy options comprising the proposed Aviation Energy Conservation Program, as previously presented in Table 4, is provided below. The 16 policy options listed in Table 1 which did not become a part of the proposed AECP are presented thereafter. More detailed information on the options is available in Volumes I and II of the supporting study.

1. Active Controls - In most current commercial aircraft, mechanical and electronic devices, in combination with the aerodynamic control surfaces, augment inherent stability and control characteristics. Active controls for aircraft would involve the coordination of aerodynamic surfaces and advanced flight computers and electrohydraulic systems to increase the inherent stability of the aircraft. By relaxing static stability, controlling maneuver load, actively suppressing flutter, and alleviating gust loads, active controls result in reduced structural weight and improved aerodynamic performance. The reduction in weight results in fewer gallons of fuel being burned and a proportional increase in RTM/G.

2. Airport Surface Traffic Control (ASTC) - This option is an analog ground surveillance radar system which provides accurate information to controllers on aircraft location. Currently, controllers determine aircraft location visually, when weather permits; by pilot position reports via voice radio, when the controllers are unable to see; or by using the current Airport Surveillance Detection Equipment (ASDE) which is installed at high density airports. Current systems severely limit the capacity of ground control and constrain the rate at which aircraft can be handled for the airport. ASTC will be an improvement over the current ASDE and will effectively raise ground control capacity. This should reduce overall delay, resulting in fewer gallons of fuel being wasted due to delay, and a higher value for RTM/G.

3. Capacity Restraint - This option is simply the substitution of a smaller aircraft for the existing aircraft on a route (e.g., substituting a B727 for a B707). The load factor will be higher, assuming passenger demand remains constant, for the smaller aircraft, but, more importantly, the smaller aircraft

will burn less fuel. By carrying the same passenger load on a route and using less fuel, this practice results in an increase in RTM/G.

4. Climb Procedures in Terminal Control Areas (TCA's) - Federal Aviation Regulation (FAR) 91.70(a) states that " . . . no person may operate an aircraft below 10,000 feet MSL at an indicated airspeed of more than 250 knots (288 mph)." Unfortunately, many aircraft have optimal climb rates which are greater than 250 knots, so that FAR 91.70(a) causes these aircraft to burn more fuel than necessary while under 10,000 feet. For example, the optimal climb speed for a B727-200 is 320 knots. By revising FAR 91.70(a) to permit higher speed climb rates, fewer gallons will be consumed, thereby raising RTM/G. Safety considerations and noise abatement procedures may limit full use of optimal climb rates.

5. Discrete Address Beacon System (DABS)/Automatic Traffic Advisory and Resolution System (ATARS) - DABS is a cooperative surveillance system with an integral data link capability which is capable of supporting ATARS. Both of these items are components of the UG3RD Air Traffic Control system, and they enhance the air traffic controller's capabilities by providing for discrete air-ground communication and improved efficiency in applying separation standards. The increased system capacity should lead to less aircraft delay, fewer gallons of fuel being burned, and an increase in RTM/G.

6. Flow Control Automation - This includes a comprehensive package of options including ARTS III enhancements to improve terminal area metering and spacing, en route enhancement to support area navigation techniques, and provide en route metering and advanced (circa 1990) metering and spacing. By reducing spacing between aircraft, the effective capacity of airports will rise, decreasing delay. The reduction in delay will result in fewer gallons being wasted, thereby raising RTM/G.

7. Fog Dispersal Systems - The existence of fogs at airports reduces pilot's visibility needed for visual ground reference in the approach, touchdown, and rollout zones of the airport runway. As a result, the airport requires Instrument Flight Rules (IFR) which have the result of lowering effective airport capacity from its Visual Flight Rules (VFR) level. A fog dispersal system would prevent fogs from reducing airport capacity, thereby decreasing aircraft delay (hence, gallons burned).

8. Fuel Advisory Departure (FAD) Procedures - FAD is an airport-specific flow control system which transfers airborne delay to ground delay by altering actual aircraft departure times consistent with acceptance rates at the destination airport. Since an aircraft burns far less fuel while on the ground or at the gate, a given amount of a system delay results in much less fuel being wasted when the FAD procedures are used.

9. Large Air Cargo Transports - Considerable economies in cargo handling can be obtained by using high capacity air cargo transports (freighters). The largest air cargo transport currently available is the B747F with a cargo capacity of 127.5 tons. An advanced technology cargo transport carrying up to 180 tons would have a higher RTM/G value because of its greater capacity as well as its design (supercritical wings, new engines, etc.).

10. Lighter-Than-Air (LTA) Cargo Vehicles - Since LTA's do not use fuel for lift, but only for propulsion, they can carry a given cargo load using less fuel than a conventional air cargo transport. This results in increased efficiency and higher RTM/G.

11. Load to Aft Center of Gravity (CG) - By allocating cargo and passenger weight so that the aircraft center of gravity is at the aft limit specified as safe for aerodynamic stability, aircraft drag is reduced. This drag reduction results in less fuel being burned and, thereby, increases RTM/G.

12. Microwave Landing Systems (MLS) - MLS is a component of the UG3RD Air Traffic Control System and provides improved measurement guidance during the descent of the aircraft. This permits descent and approach profiles to be used which are optimal with respect to fuel consumption.

13. New Near Term (NNT) Aircraft - The NNT aircraft is a 1980 aircraft employing JT10D/CFM56 engines, winglets, supercritical airfoils, active controls, and composite materials. It is 38 percent more fuel efficient than conventional aircraft and will raise the overall RTM/G when used to replace obsolete, fuel-inefficient aircraft.

14. On-Board Performance Computers - A computer, on-board the aircraft, optimizes fuel utilization by permitting fuel conservative descent profiles, by monitoring aircraft health, and by performing other functions which result in the most efficient performance of the aircraft with respect to fuel usage.

15. Optimum Descent - Conventional descent procedures for aircraft involve a step-down approach; that is, the aircraft drops to a lower altitude, flies at that altitude for a while, then drops to an even lower altitude, etc. This procedure is not optimal with respect to fuel consumption. The idle-thrust descent and/or NASA landing approach procedure are optimal descent profiles in that they minimize fuel usage during the aircraft descent phase. Safety-related problems will have to be resolved before full implementation can proceed.

16. Optimum Altitude - Fuel consumption by an aircraft depends on several factors, one of which is the altitude at which the aircraft flies. Given aircraft cruise speed and weight, there is an optimum altitude for minimum fuel consumption for the aircraft. Currently, aircraft are flying, on the average, at altitudes below the optimum altitude. By increasing the average altitude of an aircraft, its fuel consumption will decline.

17. Optimum Cruise Speed - Cruise speed also affects the rate of fuel consumption for an aircraft. Currently, aircraft speeds are above the optimal speed for minimum fuel consumption. By slowing down to the optimum cruise speed, each aircraft will reduce its fuel consumption.

18. Post-UG3RD Air Traffic Control - The UG3RD Air Traffic Control System will probably be replaced with a new system in the 1990's. This new, post-UG3RD system has not been completely defined, but is expected to use advanced automated systems, such as the Global Positioning System (GPS). GPS uses satellites to provide high-accuracy navigation information to aircraft. Improvements in operational procedures resulting from the installation of the post-UG3RD ATC system are expected to have a beneficial effect on fuel consumption.

19. Reduce Fuel Tankering - Because of differing prices and availability of fuel at various airports, aircraft operators tend to carry more fuel than that needed for a particular flight. This practice is called "tankering" and is fuel-inefficient because more fuel is burned in flight due to the added weight of the tankered fuel. Fuel reservation systems and education campaigns to illustrate the economics of tankering could greatly reduce this practice. Reduced fuel tankering would result in less fuel burned on a particular flight, thereby raising RTM/G.

20. Reseat Existing Aircraft - By increasing the number of seats in existing air carrier aircraft, the potential passenger load is thereby raised. Reducing first class seats and providing smaller seats in coach have been the general approaches. The increase in RTMs resulting from the reseating of aircraft exceeds the increase in the number of gallons consumed, as long as load factors do not decline.

21. Area Navigation (RNAV) - RNAV provides flexibility for airspace users and air traffic control for maximizing utilization of the airspace. This capability allows reduction in actual distance flown as opposed to the conventional circuitous navigation along airways and decreases congestion in the airspace with attendant fuel savings.

22. Simulators - Air carriers and general aviation are now using simulator training for flight crews in lieu of actual training flights. By maximizing the use of aircraft simulators, the fuel normally expended in actual flying for training purposes can be reduced.

23. Snow-Ice Removal Equipment - The time required to open runways after a snowfall is highly variable, depending in large measure upon the intensity of the snowfall and the availability of snow-ice removal equipment. Increasing the availability of such equipment, as a proposed amendment to the Airport and Airway Development Act of 1970 would do, would assist in the reduction of aircraft delay due to snow and ice problems.

24. Taxi on Fewer Engines - Aircraft operating on the ground do not need to use all of the engines on the aircraft. Considerable fuel can be saved by shut-down of one or more engines for taxiing. This option is currently employed by all users to some extent, but it could be increased for additional fuel savings.

25. Wake Vortex Avoidance Systems (WVAS) - The WVAS is a ground-based system for predicting or detecting the existence of wake vortices. The controller can relay wake turbulence warnings to the pilot so that evasive actions can be taken. The WVAS permits reduced separation standards, leading to a reduction in delay.

26. Winglets - Winglets are vertical airfoils added to the tips of each aircraft wing to reduce drag-due-to-lift and to help disperse the wingtip vortex. The primary benefit is the higher lift/drag ratio which reduces fuel consumption required

for aircraft lift at a given gross takeoff weight. Dispersal of the wingtip vortex helps somewhat in reducing the wake vortex problem.

The following 16 policy options are those from Table 3 (p. 10) which were eliminated from the proposed program as given in Table 4 (p. 14).

1. Advanced Jet Engines - A retrofit program beginning in the mid-1980's which replaces conventional jet engines with an advanced turbofan characterized by an 8 percent reduction in specific fuel consumption versus the JT10D/CFM56.

2. Aft Body Modifications - Modifications to the engine aft body using improved materials and a general drag reduction program (control surface rigging items, surface irregularity items, etc.). The modifications would be performed on the existing air carrier fleet on a retrofit basis.

3. Alternate Ground Movement of Aircraft - The use of towing methods for moving aircraft from the gate to the runway prior to takeoff and the return leg upon landing. Powered landing gear, cable tow, and articulated tractors are just three possible alternate power sources for the ground movement of aircraft.

4. Composite Materials Retrofit - The retrofitting of select aircraft structures (e.g., fairings, secondary body structures) in order to reduce aircraft weight. The lighter weight aircraft would then use less fuel.

5. Derivative Aircraft - Replacement of portions of the existing fleet with derivatives of the DC-9, DC-10, and L-1011. The derivative aircraft would employ new engines, winglets, composites, and other state-of-the-art technologies. The DC-9 derivative would replace 25 percent of the B737/DC-9 fleet, the DC-10 derivative would replace 40 percent of the B707/DC-8 fleet, and the L-1011 derivative would replace future DC-10 and B-747 orders.

6. Digital Electronic Propulsion Control (DEPC) Systems - A prime reliable microcomputer capable of meeting the control requirements of turbine engines will do away with the need for the relatively less efficient hydromechanical control systems in use today. The DEPC system would monitor fuel flow in a real-time environment and reduce fuel consumption.

7. General Aviation (GA) Runways - This option involves the construction of short runways at large hub airports to service the GA population. When air carrier and GA aircraft are involved in mixed operations on the same runways, separation

standards are higher than would be the case for air carrier operations alone. Large, heavy aircraft used primarily by air carriers create wake vortices which require greater separation standards to ensure that following aircraft will not encounter wake turbulence. By providing runways specifically for smaller GA aircraft, overall airport capacity is higher and the acceptance rate on the air carrier runways rises due to reduced separations. Thus, delay with its accompanying negative impact on fuel burn, is reduced. This option is limited due to the unavailability of land around major hub airports.

8. JT8D Retrofit - The reengining of all four engine narrow-body aircraft with the refanned JT8D-209/-217 engines would improve significantly the fuel efficiency of those aircraft. For most DC-8's and B707's, 10 percent less fuel would be used to carry the same loads.

9. JT10D/CFM56 Retrofit - The reengining of all B727's and B737's/ DC-9's with the current technology JT10D/CFM56 engines would result in 8 to 10 percent less fuel being consumed to carry the same aircraft loads.

10. Performance Measurement and Evaluation Program (PMEP) - The PMEP is a computerized system to monitor the fuel performance of each aircraft. The replacement of deteriorated engine parts and the overhaul of jet engines would be revised in light of the PMEP results. By maintaining engine performance at acceptable levels, fuel usage by inefficient engines will be avoided.

11. STOL Aircraft - The short takeoff and landing (STOL) aircraft could serve select commuter markets and reduce airport congestion by replacing several, smaller commuter aircraft.

12. STOL-Ports/Strips - Short takeoff and landing (STOL) aircraft require sufficiently different controller operational procedures, and separate STOL operations from those of the air carriers are preferable. The construction of STOL dedicated airports or of STOL-strips at existing airports will both expand airport capacity and reduce air carrier separation standards.

13. Supercritical Airfoil Retrofit - The supercritical airfoil produces a higher lift coefficient for a given wing weight or produces the same lift with a lighter wing. In both cases, fuel consumption is reduced.

14. Temporary Construction Runways - Short, temporary parallel runways could be used during airport construction and reconstruction to reduce the effect of runway closures on aviation

system capacity and delay. By installing a short runway parallel to the runway being resurfaced or constructed, the capacity loss can be reduced to the extent small aircraft can use the additional short runway.

15. Wake Vortex Class Sequencing - Wake turbulence is wingtip generated vortices. Large heavy aircraft create more turbulence and air traffic control spaces aircraft during takeoff and departure based on wake turbulence potential and the size aircraft next in the queue. By proper sequencing of aircraft in the queue, wake turbulence spacing can be diminished.

16. Wingtip Extensions - Wingtip extensions are three to four foot segments added to the end of each wingtip to raise the lift/drag ratio and disperse the wingtip vortex.